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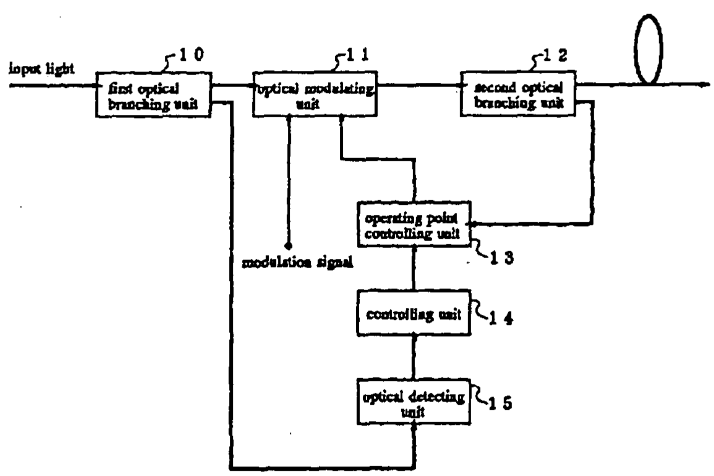
(54) **Optical communication apparatus and optical add/drop apparatus**

(57) The present invention relates to an optical communication apparatus for detecting the intensity of light in an optical modulator or the intensity of a modulation signal and for controlling the operating point of the optical modulator based on the result of detection. In the optical communication apparatus having such a configuration, the operating point of the optical modulator can be kept stable even when the input light or the modulation signal is temporarily non-existent in the optical communication apparatus.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention, an optical communication apparatus which transmits wavelength-division multiplexed signal light, relates to an optical communication apparatus whose operation is stabilized irrespective of presence/absence of input light or a modulated signal to be transmitted, as well as to an optical add/drop apparatus using such an optical communication apparatus as an addition apparatus.

2. Description of the Related Art

[0002] Ultra-long-distance and large-capacity optical communication apparatuses are now required to construct future multimedia networks. Concentrated studies are now being made of the wavelength-division multiplexing as a method for realizing large-capacity apparatuses in view of such advantages that it can effectively utilize a wide bandwidth and a large capacity of an optical fiber.

[0003] In particular, studies are in progress about an optical add/drop apparatuses of the wavelength-division multiplexing method and optical modulators used in the addition section of such an optical add/drop apparatus that is required in each node of the lightwave network.

[0004] In the Mach-Zehnder interferometer type optical modulators (hereinafter abbreviated as "MZ modulator") that are used as optical modulators in conventional optical communication apparatuses, it is necessary to stabilize the output optical signal with respect to a variation and the variation with temperature and time. Japanese Patent Laid-Open No. 251815/1991 discloses an operating point control circuit for controlling the operating point of an MZ modulator intended for this purpose.

[0005] FIG. 20 is a block diagram of an MZ modulator having this conventional operating point control circuit.

[0006] As shown in FIG. 20, light exit from a light source 310 such as a laser diode (hereinafter abbreviated as "LD") is entered to an MZ modulator 311. A modulation signal including information to be sent and a low-frequency signal of a predetermined frequency f0 that is outputted from a low-frequency oscillator 324 are inputted to a variable gain amplifier 313. The variable gain amplifier 313 superimposes the low-frequency signal of the predetermined frequency f0 on the modulation signal and outputs it, which is then inputted to one modulation-input terminal of the MZ modulator 311 via an amplifier 314 for obtaining a predetermined signal level and a coupling capacitor 315. A bias T circuit consisting of an inductor 316 and a capacitor 317 is connected to the other modulation-input terminal of the MZ modulator 311. The capacitor 317 is grounded via resistor 318. A portion consisting of the amplifier 314, the coupling capacitor 315, the bias T circuit, and the resistor 318 are equivalent to a drive circuit of the MZ modulator 311.

[0007] The MZ modulator 311 modulates light that is supplied from the light source 310 with a signal that is given by the drive circuit and outputs a resulting signal.

[0008] Part of an optical output of the MZ modulator 311 is branched and taken out by an optical coupler 312. The branched part of the optical output is detected by a photoelectric converter 319 such as a photodiode (hereinafter abbreviated as "PD"), and the detection signal is amplified by a buffer amplifier 320 that selectively amplifies a frequency component of f0 and inputted to a multiplier 321. The low-frequency signal that is outputted from the low-frequency oscillator 324 is also inputted to the multiplier 321. The multiplier 321 compares the phases of the signal that is inputted from the buffer amplifier 320 and the low-frequency signal that is inputted from the low-frequency oscillator 324, and outputs a signal in accordance with a phase difference.

[0009] Therefore, the multiplier 321 can detect the low-frequency signal of the predetermined frequency f0 that was superimposed by the variable gain amplifier 313.

[0010] An output signal of the multiplier 321 is inputted to one input terminal of a differential amplifier 323 via a low-pass filter (hereinafter abbreviated as "LPF") 322 that allows passage of a frequency component of the predetermined frequency f0 or less. On the other hand, the other input terminal of the differential amplifier 323 is grounded. An output of the differential amplifier 323 is inputted to the inductor 316 of the bias T circuit as an error signal to be used for moving the operating point of the MZ modulator 311, whereby the bias value is variably controlled so as to correct the operating point.

[0011] In the MZ modulator having the above configuration, the superimposed low-frequency signal of the frequency f0 does not appear in the output light when the bias value is in the optimum state.

[0012] FIG. 21 is a waveform diagram showing an operation in a state that the operating point drifts in the MZ modulator having the above circuit configuration. Part (a) of FIG. 21 shows input/output characteristics of the MZ modulator, in which curve B represents an input/output characteristic in a case where the operating point has drifted to the high-voltage side from that of curve A and curve C represents a case where the operating point has drifted to the low-voltage side from that of curve A. Part (b) of FIG.21 shows a waveform of an input signal and parts (c), (c1), and (c2) of FIG.21 show waveforms of output optical signals of the respective input/output characteristics.

[0013] As shown in FIG. 21, when the operating point has drifted to the high-voltage side or the low-voltage side, low-frequency signal of the frequency f0

superimposed in output light appears with a phase that is inverted by 180° depending on the drift directi n. Therefore, the bias voltage can be controlled by using a signal coming from the multiplier 321, whereby the drift of the operating point can be compensated for.

[0014] In this manner, a drift of the operating point can be compensated for by taking out a low-frequency signal from output light that has been produced by modulating input light with a modulation signal and the low-frequency signal and then comparing its phase with the phase of the original low-frequency signal. Therefore, the operating point control circuit described above can control the operating point to stabilize it in a case where input light (output light) and a modulation signal exist.

[0015] FIG. 22 is a block diagram showing a conventional optical add/drop apparatus.

[0016] As shown in FIG. 22, after wavelength-division multiplexed signal light transmitting through an optical transmission line is amplified to a predetermined light intensity, it is then entered to an OADM (optical add-drop multiplexer) node section 350 which adds/drops on the wavelength-division multiplexed signal light. Signal light beams of predetermined wavelengths are dropped by the OADM node section 350 and subjected to receiving operations in optical dropping sections 352 that are provided in the same number of signal light beams to be branched by an optical coupler 351. Signal light beams to be added by the OADM node section 350 is generated by optical addition sections 355. The optical addition sections 355 are provided in the same number of signal light beams of respective wavelengths to be added by the OADM node section 350. The added signal light beams and the signal light that has not been dropped in the OADM node section 350 are wavelength-division multiplexed, amplified, and then outputted to the optical transmission line.

[0017] In each optical addition section 355 of this optical add/drop apparatus, light that is exit from an LD 360 for generating light of a particular wavelength is amplified by an optical amplifier 361. Output light of the optical amplifier 361 is modulated by an optical modulator 362 having the above-described operating point control circuit. The modulated optical signal is amplified by an optical amplifier 363 and then entered to an optical coupler 354. The optical coupler 354 adds this optical signal to the OADM node section 350 together with optical signals of other wavelengths that have been generated by other optical addition sections 355 having the same configuration.

[0018] Incidentally, in the MZ modulator 311 shown in FIG. 20, the following problem occurs when there is a short break in which the input light entered to the MZ modulator 311 is temporarily non-existent and then recovers.

[0019] When the input light no longer exists, there is no light output to be branched by the optical coupler 312 and hence the operating point becomes indefinite. That is, in part (b) of FIG. 21, it is impossible to judge wheth r the bias voltage Vb is (1) 0 V or less, (2) greater than 0 V and smaller than Vp, or (3) Vp or mor .

[0020] If the input light recovers in such an indefinite state, in case (2) the optimum operating point is established by the operation of the bias T circuit. However, the optimum operating point is not established in cases (1) and (3); Vb is predetermined at 0 V in case (1) and Vb is predetermined at Vp in case (3).

[0021] By these reasons, when a short break occurs in the input light that is incident on the MZ modulator 311, the optimum operating point is not necessarily obtained.

[0022] Hitherto, the above problem did not occur because the MZ modulator 311 was used in terminal stations or the like where no short breaks occur on the input light. However, where the MZ modulator 311 is used in each optical addition section 355 of the optical add/drop apparatus of FIG. 22, it is necessary to switch the wavelength of addition light to a wavelength that is not used in a wavelength-division multiplexed signal transmitting through the optical transmission line. This necessarily causes, during such wavelength switching, a state where no input light exists. Therefore, the solving the problem of being in the above indefinite state is a particularly important issue.

[0023] On the other hand, in the optical add/drop apparatus of FIG. 22, when there is no input light to the optical modulator 362, ASE (amplified spontaneous emission), which is a noise level spontaneously generated by the optical amplifiers 361 and 363, is outputted to the optical transmission line. Further, each optical addition section 355 does not always have a modulation signal to be added. When no such modulation signal exists, not only ASE but also input light that is not modulated with any modulation signals are outputted to the optical transmission line.

[0024] Further, in optical communication networks, the judgement of malfunctions occurring therein is based on the light intensity. Therefore, the malfunction cannot be judged if ASE or input light that is not modulated with a modulation signal is inputted to an optical transmission line.

SUMMARY OF THE INVENTION

[0025] The first object of the present invention is to provide an optical communication apparatus for keeping the operating point of an optical modulator stable even when the input light or the modulation signal is temporarily non-existent in the optical communication apparatus.

[0026] The object is attained by the optical communication apparatus for detecting the light intensity of light in an optical modulator or the intensity of a modulation signal and for controlling the operating point of the optical modulator based on the result of detection.

[0027] The second object of the present invention is to provide an optical communication apparatus which

does not exit ASE nor input light that is not modulated with an modulation signal even when the input light or the modulation signal is temporarily non-existent in the optical communication apparatus.

[0028] The object is attained by the optical communication apparatus for detecting the intensity of light in an optical modulator or the intensity of a modulation signal and for regulating the intensity of light transmitted to an optical transmission line from the optical modulator based on the result of detection.

[0029] The regulation of the light intensity is regulated, for example, by an optical attenuator for attenuating the intensity of light entered to the optical modulator or by an optical attenuator for attenuating the intensity of light exit from the optical modulator. As another example, switching the optical modulator regulates the regulation of the light intensity.

[0030] As one of aspects of the present invention, the optical communication apparatus can be used in an optical add/drop apparatus for adding and dropping an optical signal to and from wavelength-division multiplexed optical signal.

[0031] As another aspect of the present invention, the optical add/drop apparatus, even when there are any unused communication apparatuses, since the input light or the output of the optical modulator of an unused addition apparatus and the modulation signal are monitored, the operating point of the optical modulator is kept stable and neither ASE nor input light that is not modulated with a modulation signal is exit from such an addition apparatus.

[0032] Besides, another objects and characteristics of the present invention will be described specifically as follows referring to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033]

FIG. 1 is a block diagram of the optical communication apparatus according to the first embodiment;
FIG. 2 is a block diagram of the optical communication apparatus according to the second embodiment;
FIG. 3 is a block diagram of the optical communication apparatus according to the third embodiment;
FIG. 4 is a block diagram of the optical communication apparatus according to the fourth embodiment;
FIG. 5 is a block diagram of the optical communication apparatus according to the fifth embodiment;
FIG. 6 is a block diagram of the optical communication apparatus according to the sixth embodiment;
FIG. 7 is a block diagram of the optical communication apparatus according to the seventh embodiment;
FIG. 8 is a block diagram of the optical communication apparatus according to the eighth embodiment;
FIG. 9 is a block diagram of the optical communication apparatus according to the ninth embodiment;
FIG. 10 is a block diagram of the optical communication apparatus according to the tenth embodiment;
FIG. 11 is a block diagram of the optical communication apparatus according to the eleventh embodiment;
FIG. 12 is a block diagram of the optical communication apparatus according to the twelfth embodiment;
FIG. 13 is a block diagram of the optical communication apparatus according to the thirteenth embodiment;
FIG. 14 is a block diagram of the optical add/drop apparatus according to the fourteenth embodiment;
FIG. 15 is a block diagram of the optical add/drop apparatus according to the fifteenth embodiment;
FIG. 16 is a block diagram of the optical add/drop apparatus according to the sixteenth embodiment;
FIG. 17 is a block diagram of the optical add/drop apparatus according to the seventeenth embodiment;
FIG. 18 is a block diagram of the optical add/drop apparatus according to the eighteenth embodiment;
FIG. 19 is a block diagram of the optical add/drop apparatus according to the nineteenth embodiment;
FIG. 20 is a block diagram of an MZ modulator having a conventional operating point control circuit;
FIG. 21 is a waveform diagram showing an operation in a state that the operating point drifts; and
FIG. 22 is a block diagram of a conventional optical add/drop apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0034] The embodiment of optical communication apparatuses according to the invention will be hereinafter described with reference to the accompanying drawings. Besides, the same reference numerals of each figure indicate that they have the same constructions and description thereof will be omitted in the following.

[0035] The optical communication apparatus according to the first embodiment will be explained based on the accompanying figure.

[0036] In FIG.1, this optical communication apparatus is composed of optical branching unit 10 and 12, an optical modulating unit 11, an operating point controlling unit 13, a controlling unit 14, and an optical detecting unit 15.

[0037] Light entered to an input port is branched by the optical branching unit 10 that branches light into two. The first branched input light that has been branched off by the optical branching unit 10 is modulated by the optical modulating unit 11 in accordance with a modulation signal to be transmitted. A modulated optical signal that

is outputted from the optical modulating unit 11 is branched by the optical branching unit 12 that branches light into two.

[0038] The first optical signal branched off by the optical branching unit 12 is exit to an output port. On the other hand, the second optical signal branched off by the optical branching unit 12 is entered to the operating point controlling unit 13 that controls the operating point of the optical modulating unit 11 is entered.

[0039] The operating point controlling unit 13 can keep the operating point of the optical modulating unit 11 in the optimum state when receiving a part of the optical signal that is exit from the optical modulating unit 11.

[0040] On the other hand, the optical detecting unit 15 detects the intensity of the second branched input light that has been branched off by the optical branching unit 10, and outputs a signal in accordance with the detected light intensity. For example, the optical detecting unit 15 outputs a signal when the light intensity is a predetermined value or less. Alternatively, the optical detecting unit 15 outputs a signal when the light intensity is zero. So that the operating point controlling unit 13 can keep the operating point stable, the signal that is generated in accordance with the light intensity is inputted to the controlling unit 14 that controls the operation of the operating point controlling unit 13.

[0041] When receiving a signal from the optical detecting unit 15, the controlling unit 14 controls stopping the operation of the operating point controlling unit 13. Alternatively, the controlling unit 14 controls the operating point controlling unit 13 so that it keeps the operating point in a limited range.

[0042] In this manner, the optical detecting unit 15 can detect whether the intensity of input light is a predetermined value or less. Therefore, when the intensity of the input light is the predetermined value or less, the controlling unit 14 can control, in accordance with the output of the optical detecting unit 15, the operating point controlling unit 13 so that it can keep the operating point stable. As a result, in the optical communication apparatus having the above configuration, the operating point can be kept stable even when input light is temporarily non-existent.

[0043] Naturally, the optical detecting unit 15 does not output any signals when the intensity of input light is larger than the predetermined value so as to use the optical modulating unit 11. Therefore, the operating point controlling unit 13 controls the operating point to the optimum value based only on the output of the optical modulating unit 11 that is entered via the optical branching unit 12.

[0044] Next, the optical communication apparatus according to the second embodiment will be explained based on the accompanying figure.

[0045] As shown in FIG. 2, the optical communication apparatus is composed of an optical modulating unit 11, an optical branching unit 21, an operating point controlling unit 13, a controlling unit 14, and an optical detecting unit 23.

[0046] Light entered to an input port is modulated by the optical modulating unit 11. The modulated optical signal is branched by the optical branching unit 21 that branches light into three.

[0047] The first optical signal that has been branched off by the optical branching unit 21 is exit to an output port. On the other hand, the second optical signal that has been branched off by the optical branching unit 21 is entered to the operating point controlling unit 13.

[0048] On the other hand, the optical detecting unit 23 detects the light intensity of the third optical signal branched off by the optical branching unit 21, and outputs a signal in accordance with the detected light intensity. For example, the optical detecting unit 23 outputs a signal when the light intensity of the modulated optical signal is a predetermined value or less. Alternatively, the optical detecting unit 23 outputs a signal when the light intensity is zero. The signal that is generated in accordance with the light intensity is inputted to the controlling unit 14.

[0049] When the intensity of input light is a predetermined value or less, the intensity of a modulated optical signal that is exit from the optical modulating unit 11 is also a predetermined value or less. Because of this, whether the intensity of the input light is the predetermined value or less can be detected by detecting the light intensity of the modulated optical signal with the optical detecting unit 23. Therefore, the controlling unit 14 can control, in accordance with the output of the optical detecting unit 23, the operating point controlling unit 13 so that it can keep the operating point stable. As a result, in the optical communication apparatus having the above configuration, the operating point can be kept stable even when input light is temporarily non-existent.

[0050] Naturally, the optical detecting unit 15 does not output any signals when the intensity of input light is larger than the predetermined value so as to use the optical modulating unit 11. Therefore, the operating point controlling unit 13 controls the operating point to the optimum value only based on the output of the optical modulating unit 11 that is entered via the optical branching unit 21.

[0051] Next, the optical communication apparatus according to the third embodiment will be explained based on the accompanying figure.

[0052] As shown in FIG. 3, the optical communication apparatus is composed of an optical modulating unit 11, an optical branching unit 12, an operating point controlling unit 13, a controlling unit 25, and a modulation signal detecting unit 26.

[0053] Light entered to an input port is modulated by the optical modulating unit 11. A modulated optical signal is branched by the optical branching unit 12.

[0054] The first optical signal branched off by the optical branching unit 12 is exit to an output port. On the

other hand, the second optical signal branched off by the optical branching unit 12 is entered to the operating point controlling unit 13.

[0055] A modulation signal to be transmitted is inputted to not only the optical modulating unit 11 but also the modulation signal detecting unit 26. The modulation signal detecting unit 26 detects the intensity of the modulation signal and outputs a signal in accordance with the detected signal intensity. For example, the modulation signal detecting unit 26 outputs a signal when the signal intensity becomes a predetermined value or less. Alternatively, the modulation signal detecting unit 26 outputs a signal when the signal intensity becomes zero. The signal that is generated in accordance with the signal intensity is inputted to the controlling unit 25.

[0056] When receiving a signal from the modulation signal detecting unit 26, the controlling unit 25 stops the operation of the operating point controlling unit 13. Alternatively, the controlling unit 25 controls the operating point controlling unit 13 so that it keeps the operating point in a limited range.

[0057] In this manner, the modulation signal detecting unit 26 can detect whether the intensity of a modulation signal is a predetermined value or less. Therefore, when the intensity of the modulation signal is the predetermined value or less, the controlling unit 25 can control, in accordance with the output of the modulation signal detecting unit 26, the operating point controlling unit 13 so that it keeps the operating point stable. As a result, in the optical communication apparatus having the above configuration, the operating point can be kept stable even when modulation signal is temporarily nonexistent.

[0058] Naturally, the modulation signal detecting unit 26 does not output any signals when there is information to send and the intensity of a modulation signal to be transmitted is larger than the predetermined value. Therefore, the operating point controlling unit 13 controls the operating point to the optimum value only based on the output of the optical modulating unit 11 that is entered via the optical branching unit 12.

[0059] Next, the optical communication apparatus according to the fourth embodiment will be explained based on the accompanying figure.

[0060] In FIG.4, this optical communication apparatus is composed of an optical branching unit 10, an optical modulating unit 11, an optical attenuating unit 31, an attenuation amount controlling unit 32, and an optical detecting unit 33.

[0061] FIG. 4 shows a configuration in which first branched input light that is exit from the optical branching unit 10 is exit to an output port via the optical attenuating unit 31 and the optical modulating unit 11.

[0062] On the other hand, as shown with broken lines in the same figure, the optical communication apparatus can be configured as the output light is exit to an output port via the optical modulating unit 11 and the optical attenuating unit 13.

[0063] Light entered to an input port is branched by the optical branching unit 10. The first branched input light that has been branched off by the optical branching unit 10 is entered, via the optical attenuating unit 31, to the optical modulating unit 11, where it is modulated. A modulated optical signal that is exit from the optical modulating unit 11 is exit to the output port.

[0064] The optical attenuating unit 31 trajects or attenuates it to predetermined light intensity (including zero). Alternatively, the optical attenuating unit 31 is a single input/plural output optical switch. When the optical attenuating unit 31 is such an optical switch, one output terminal is connected to the optical modulating unit 11 and the other output terminal(s) are not connected to anything.

[0065] On the other hand, the optical detecting unit 33 detects the intensity of the second branched input light that has been branched off by the optical branching unit 10, and outputs a signal in accordance with the detected light intensity. For example, the optical detecting unit 33 outputs a signal when the light intensity is a predetermined value or less. Or, the optical detecting unit 33 outputs a signal when the light intensity is zero. The signal that is generated in accordance with the light intensity is inputted to the attenuation amount controlling unit 32.

[0066] The attenuation amount controlling unit 32 controls the optical attenuating unit 31. That is, in accordance with a signal that is outputted from the optical detecting unit 33, the attenuation amount controlling unit 32 controls the optical attenuating unit 31 so that it attenuates the input light to the predetermined intensity. Alternatively, where the optical attenuating unit 31 is an optical switch, in accordance with a signal that is outputted from the optical detecting unit 33, the attenuation amount controlling unit 32 switches the output of inputted light to an output terminal to which nothing is connected.

[0067] In this manner, the optical detecting unit 33 can detect whether the intensity of input light is a predetermined value or less. Therefore, when the intensity of the input light is the predetermined value or less, the attenuation amount controlling unit 32 can output inputted light to the optical modulating unit 11 attenuating it to predetermined light intensity by controlling the optical attenuating unit 31 in accordance with the output of the optical detecting unit 33. Alternatively, the attenuation amount controlling unit 32 can output the input light to a terminal that is not connected to the optical modulating unit 11. As a result, in the optical communication apparatus having the above configuration, ASE is not exit to the output port when no input light exists.

[0068] Naturally, the optical detecting unit 33 does not output any signals when the intensity of input light is larger than the predetermined value so as to use the optical modulating unit 11. At this time, the attenuation amount controlling unit 32 controls the optical attenuating unit 31 so as to traject the input light or switch to the

terminal that is connected to the optical modulating unit 11.

[0069] Next, the optical communication apparatus according to the fifth embodiment will be explained based on the accompanying figure.

[0070] In FIG. 5, this optical communication apparatus is composed of an optical branching unit 10, an optical modulating unit 11, an optical detecting unit 33, and a modulation controlling unit 35.

[0071] Light entered to an input port is branched by the optical branching unit 10. The first branched input light that has been branched off by the optical branching unit 10 is modulated by the optical modulating unit 11, and the modulated optical signal is exit to an output port.

[0072] On the other hand, the optical detecting unit 33 detects the intensity of the second branched input light that has been branched off by the optical branching unit 10, and outputs a signal in accordance with the detected light intensity. The signal that is generated in accordance with the light intensity is inputted to the modulation controlling unit 35.

[0073] The modulation controlling unit 35 controls the optical modulating unit 11. That is, in accordance with the signal that is outputted from the optical detecting unit 33, the modulation controlling unit 35 controls the optical modulating unit 11 so that it attenuates the input light to the predetermined intensity. For example, the modulation controlling unit 35 can prevent the optical modulating unit 11 from producing any output by not supplying any energy to the optical modulating unit 11. Alternatively, where the optical modulating unit 11 is an MZ modulator, this can be done by shifting the phases of branched input light beams transmitting through two respective optical waveguides in the MZ modulator by forming a phase difference of 180°. Alternatively, where the optical modulating unit 11 utilizes the acousto-optical effect, this can be done by applying to it an RF signal for selecting a wavelength other than the wavelength of the input light.

[0074] In this manner, the optical detecting unit 33 can detect whether the intensity of input light is a predetermined value or less. Therefore, when the intensity of the input light is the predetermined value or less, the modulation controlling unit 35 can prevent the optical modulating unit 11 from producing any output by controlling it in accordance with the output of the optical detecting unit 33. As a result, in the optical communication apparatus having the above configuration, neither ASE nor input light that is not modulated with a modulation signal is exit to the output port even when input light exists but no modulation signal exists.

[0075] Naturally, the optical detecting unit 33 does not output any signals when the intensity of input light is larger than the predetermined value so as to use the optical modulating unit 11. At this time, the optical modulating unit 11 operates normally as a modulating unit because it does not receive a signal from the modulation controlling unit 35.

[0076] Next, the optical communication apparatus according to the sixth embodiment will be explained based on the accompanying figure.

In FIG. 6,this optical communication apparatus is composed of an optical attenuating unit 31, an optical modulating unit 11, an attenuation amount controlling unit 41, and a modulation signal detecting unit 42.

[0077] FIG. 6 shows a configuration in which light entered to an input port is exit to an output port via the optical attenuating unit 31 and the optical modulating unit 11.

[0078] On the other hand, as shown with broken lines in the same figure, the optical communication apparatus can be configured as the output light is exit to an output port via the optical modulating unit 11 and the optical attenuating unit 13.

[0079] Light entered to the input port is entered, via the optical attenuating unit 31, to the optical modulating unit 11, where it is modulated. A modulated optical signal that is exit from the optical modulating unit 11 is exit to the output port.

[0080] A modulation signal to be transmitted is inputted to not only the optical modulating unit 11 but also the modulation signal detecting unit 42. The modulation signal detecting unit 42 detects the intensity of the modulation signal and outputs a signal in accordance with the detected signal intensity. For example, the modulation signal detecting unit 42 outputs a signal when the signal intensity becomes a predetermined value or less. Alternatively, the modulation signal detecting unit 42 outputs a signal when the signal intensity becomes zero. The signal that is generated in accordance with the signal intensity is inputted to the attenuation amount controlling unit 41.

[0081] The attenuation amount controlling unit 41 controls the optical attenuating unit 31. That is, in accordance with a signal that is outputted from the modulation signal detecting unit 42, the attenuation amount controlling unit 41 controls the optical attenuating unit 31 so that it attenuates the input light to predetermined light intensity. Alternatively, where the optical attenuating unit 31 is an optical switch, in accordance with a signal that is outputted from the modulation signal detecting unit 33, the attenuation amount controlling unit 41 switches the output of the inputted light to an output terminal to which nothing is connected.

[0082] In this manner, the modulation signal detecting unit 42 can detect whether the intensity of a modulation signal is a predetermined value or less. Therefore, when the intensity of the modulation signal is the predetermined value or less, the attenuation amount controlling unit 41 can exit inputted light to the optical modulating unit 11 attenuating it to predetermined light intensity by controlling the optical attenuating unit 31 in accordance with the output of the modulation signal detecting unit 42. Alternatively, the attenuation amount controlling unit 41 can exit inputted light to a terminal

that is not connected to the optical modulating unit 11. As a result, in the optical communication apparatus having the above configuration, ASE is not exit to the output port when no input light exists. Further, neither ASE nor input light that is not modulated with a modulation signal is exit to the output port even when input light exists but no modulation signal exists.

[0083] Naturally, the modulation signal detecting unit 42 does not output any signals when there is information to send and the intensity of a modulation signal to be transmitted is larger than the predetermined value. At this time, the attenuation amount controlling unit 41 controls the optical attenuating unit 31 so that it trajects the input light or switches to the terminal that is connected to the optical modulating unit 11.

[0084] The optical communication apparatus according to the seventh embodiment will be explained based on the accompanying figure.

[0085] In FIG.7, this optical communication apparatus is composed of an optical modulating unit 11, a modulation signal detecting unit 42, and a modulation controlling unit 45.

[0086] Light entered to an input port is modulated by the optical modulating unit 11. A modulated optical signal is exit to an output port.

[0087] A modulation signal to be transmitted is inputted to not only the optical modulating unit 11 but also to the modulation signal detecting unit 42. The modulation signal detecting unit 42 outputs a signal in accordance with the intensity of the modulation signal. The signal that is outputted from the modulation signal detecting unit 42 is inputted to the modulation controlling unit 45.

[0088] The modulation controlling unit 45 controls the optical modulating unit 11. That is, in accordance with a signal that is outputted from the modulation signal detecting unit 42, the modulation controlling unit 45 controls the optical modulating unit 11 so that it attenuates the input light to the predetermined light intensity. For example, the modulation controlling unit 45 can prevent the optical modulating unit 11 from producing any outputs by not supplying any energy to it. Alternatively, where the optical modulating unit 11 is an MZ modulator, this can be done by shifting the phases of branched input light beams transmitting through two respective optical waveguides in the MZ modulator by forming a phase difference of 180°. As a further alternative, where the optical modulating unit 11 utilizes the acousto-optical effect, this can be done by applying to it an RF signal for selecting a wavelength other than the wavelength of the input light.

[0089] In this manner, the modulation signal detecting unit 42 can detect whether the intensity of a modulation signal is a predetermined value or less. Therefore, when the intensity of the modulation signal is the predetermined value or less, the modulation controlling unit 45 can prevent the optical modulating unit 11 from producing any outputs by controlling it. As a result, in the optical communication apparatus having the above configuration, neither ASE nor input light that is not modulated with a modulation signal is exit to the output port even when input light exists but no modulation signal exists.

[0090] Naturally, the modulation signal detecting unit 42 does not output any signals when there is information to send and the intensity of a modulation signal to be transmitted is larger than the predetermined value. At this time, the optical modulating unit 11 operates normally as a modulating unit because it does not receive a signal from the modulation controlling unit 45.

[0091] Next, the optical communication apparatus according to the eighth embodiment will be explained based on the accompanying figure.

[0092] As shown in FIG. 8, this optical communication apparatus is composed of optical branching unit 10 and 12, an optical attenuating unit 50, an optical modulating unit 11, an operating point controlling unit 13, a controlling unit 14, and an optical detecting unit 15.

[0093] Light entered to an input port is branched by the optical branching unit 10. First branched input light is entered to the optical attenuating unit 50. Output light of the optical attenuating unit 50 is modulated by the optical modulating unit 11. A modulated optical signal is branched by an optical branching unit 12. The first optical signal branched off by the optical branching unit 12 is exit to an output port. On the other hand, the second optical signal branched off by the optical branching unit 12 is entered to the operating point controlling unit 13.

[0094] The optical attenuating unit 50 trajects received input light or attenuates it to predetermined light intensity (including zero) in accordance with the intensity of the input light. Alternatively, the optical attenuating unit 50 is a single input/plural output optical switch. Where the optical attenuating unit 50 is such an optical switch, one output terminal is connected to the optical modulating unit 11 and the other output terminal(s) are not connected to anything.

[0095] On the other hand, the optical detecting unit 15 detects the intensity of second branched input light that has been branched off by the optical branching unit 10, and outputs a signal in accordance with the detected light intensity. The signal that is generated in accordance with the light intensity is inputted to the controlling unit 14.

[0096] The optical communication apparatus having the above configuration not only operates in the same manner as the optical communication apparatus according to the first embodiment of the invention but also does not exit ASE to the output port when no input light exists.

[0097] That is, the optical attenuating unit 50 judges whether the intensity of the light received is a predetermined value or less and attenuates the light received in accordance with the judgment result. Therefore, when the intensity of the light received is the predetermined value or less, the optical attenuating unit 50 attenuates

it to predetermined intensity and outputs resulting light. Alternatively, where the optical attenuating unit 50 is an optical switch, when the intensity of the light received is the predetermined value or less, the optical attenuating unit 50 switches to outputting the light received to an output terminal to which nothing is connected. Therefore, the optical communication apparatus having the above configuration does not exit ASE to the output port when no input light exists.

[0098] Naturally, the optical attenuating unit 50 trajects input light and outputs it when the intensity of the input light is larger than the predetermined value so as to use the optical modulating unit 11. Alternatively, where the optical attenuating unit 50 is an optical switch, it switches to outputting the light received to the terminal that is connected to the optical modulating unit 11.

[0099] Note that, the optical attenuating unit 50 placed at the input of the optical modulating unit 11 in this optical communication apparatus as shown in FIG. 8 can also be placed at the output of the same.

[0100] Next, the optical communication apparatus according to the ninth embodiment will be explained based on the accompanying figure.

[0101] As shown in FIG. 9, this optical communication apparatus is composed of optical branching unit 10 and 12, an optical modulating unit 55, an operating point controlling unit 13, a controlling unit 14, and an optical detecting unit 15.

[0102] Light entered to an input port is branched by the optical branching unit 10. First branched input light is modulated by the optical modulating unit 55 in accordance with a modulation signal to be transmitted. The modulated optical signal that is exit from the optical modulating unit 55 is branched by the optical branching unit 12 that branches light into two beams.

[0103] The optical modulating unit 55 controls whether to output a modulated optical signal, in accordance with the intensity of the modulation signal or the intensity of the light received.

[0104] The first optical signal branched off by the optical branching unit 12 is exit to an output port. On the other hand, the second optical signal branched off by the optical branching unit 12 is entered to the operating point controlling unit 13.

[0105] On the other hand, the optical detecting unit 15 detects the intensity of second branched input light that has been branched off by the optical branching unit 10, and outputs a signal in accordance with the detected light intensity. This signal is inputted to the controlling unit 14.

[0106] The optical communication apparatus having the above configuration not only operates in the same manner as the optical communication apparatus according to the first embodiment of the invention but also does not exit ASE to the output port when no input light exists.

[0107] The optical modulating unit 55 judges whether the intensity of the light received is a predetermined value or less or whether the intensity of the modulation signal is a predetermined value or less. As a result, the optical modulating unit 55 produces no output when the intensity of the light received is the predetermined value or less or the intensity of the modulation signal is the predetermined value or less. For example, it is possible to prevent the optical modulating unit 55 from producing any outputs by not supplying energy to it. Alternatively, where the optical modulating unit 11 is an MZ modulator, this can be done by shifting the phases of branched light beams transmitting through two respective optical waveguides in the MZ modulator by forming a phase difference of 180°. Alternatively, where the optical modulating unit 11 utilizes the acousto-optical effect, this can be done by applying to it an RF signal for selecting a wavelength other than the wavelength of the input light. Therefore, the optical communication apparatus having the above configuration does not exit ASE nor input light that is not modulated with a modulation signal even when input light exists but no modulation signal exists.

[0108] Naturally, the optical modulating unit 55 operates normally as a modulating unit when the intensity of the input light is larger than the predetermined value or when the intensity of the modulation signal is larger than the predetermined value so as to use the optical modulating unit 55.

[0109] Note that, the controlling unit 14 controlled by the optical communication apparatus according to the input light of the optical modulating unit 55 as shown in FIG. 9 can also be controlled according to the output light of the optical modulating unit 55 or a modulation signal.

[0110] Next, the optical communication apparatus according to the tenth embodiment will be explained based on the accompanying figure.

[0111] In FIG.10, this optical communication apparatus is composed of optical branching unit 10 and 12, an optical modulating unit 11, an operating point controlling unit 13, a controlling unit 14, an optical detecting unit 15, an optical attenuating unit 31, an attenuation amount controlling unit 41, and a modulation signal detecting unit 42.

[0112] Light entered to an input port is branched by the optical branching unit 10. First branched input light is entered, via the optical attenuating unit 31, to the optical modulating unit 11, where it is modulated. A modulated optical signal is branched by the optical branching unit 12.

[0113] The first optical signal branched off by the optical branching unit 12 is exit to an output port. On the other hand, the second optical signal branched off by the optical branching unit 12 is entered to the operating point controlling unit 13.

[0114] On the other hand, the optical detecting unit 15 detects the intensity of second branched input light that has been branched off by the optical branching unit

10, and outputs a signal in accordance with the detected light intensity. The signal that is generated in accordance with the light intensity is inputted to the controlling unit 14.

[0115] A modulation signal to be transmitted is inputted to not only the optical modulating unit 11 but also the modulation signal detecting unit 42. The modulation signal detecting unit 42 detects the intensity of the modulation signal and outputs a signal in accordance with the detected signal intensity, which is inputted to the attenuation amount controlling unit 41.

[0116] In this manner, the optical detecting unit 15 can detect whether the intensity of input light is a predetermined value or less. Therefore, when the intensity of the input light is the predetermined value or less, the controlling unit 14 can control, in accordance with the output of the optical detecting unit 15, the operating point controlling unit 13 so that it keeps the operating point stable. As a result, in the optical communication apparatus having the above configuration, the operating point can be kept stable even when input light is temporarily non-existent.

[0117] Naturally, the optical detecting unit 15 does not output any signals when the intensity of input light is larger than the predetermined value so as to use the optical modulating unit 11. Therefore, the operating point controlling unit 13 controls the operating point to the optimum value only based on the output of the optical modulating unit 11 that is entered via the optical branching unit 12.

[0118] Further, the modulation signal detecting unit 42 can detect whether the intensity of a modulation signal is a predetermined value or less. Therefore, when the intensity of the modulation signal is the predetermined value or less, the attenuation amount controlling unit 41 can exit inputted light to the optical modulating unit 11 attenuating it to predetermined light intensity by controlling the optical attenuating unit 31 in accordance with the output of the modulation signal detecting unit 42. Alternatively, the attenuation amount controlling unit 41 can exit the input light to a terminal that is not connected to the optical modulating unit 11. As a result, in the optical communication apparatus having the above configuration, ASE is not exit to the output port when no input light exists. Further, neither ASE nor input light that is not modulated with a modulation signal is exit to the output port even when input light exists but no modulation signal exists.

[0119] Naturally, the modulation signal detecting unit 42 does not output any signals when there is information to send and the intensity of a modulation signal to be transmitted is larger than the predetermined value. At this time, the attenuation amount controlling unit 41 controls the optical attenuating unit 31 so that it trajects input light or causes the optical attenuating unit 11 to switch to supplying the light received to the terminal that is connected to the optical modulating unit 11.

[0120] Note that, in this optical communication apparatus, the controlling unit 14 can be controlled according to the detection done by the optical detecting unit 15 on light output from the optical modulating unit 11 together with having the optical attenuating unit 31 placed at the output of optical modulating unit 11, as shown in broken lines, instead of having the optical detecting unit 15 detect input light together with having the optical attenuating unit 31 placed at the input of optical modulating unit 11, as shown in FIG. 10.

[0121] Next, the optical communication apparatus according to the eleventh embodiment will be explained based on the accompanying figure.

[0122] In FIG. 11, this optical communication apparatus is composed of optical branching unit 10 and 12, an optical modulating unit 11, an operating point controlling unit 13, a controlling unit 14, an optical detecting unit 15, a modulation signal detecting unit 42, and a modulation controlling unit 45.

[0123] Light entered to an input port is branched by the optical branching unit 10. First branched input light is entered to the optical modulating unit 11, where it is modulated. A modulated optical signal is branched by the optical branching unit 12.

[0124] The first optical signal branched off by the optical branching unit 12 is exit to an output port. On the other hand, the second optical signal branched off by the optical branching unit 12 is entered to the operating point controlling unit 13.

[0125] On the other hand, the optical detecting unit 15 detects the intensity of second branched input light that has been branched off by the optical branching unit 10, and outputs a signal in accordance with the detected light intensity, which is inputted to the controlling unit 14.

[0126] A modulation signal to be transmitted is inputted to not only the optical modulating unit 11 but also the modulation signal detecting unit 42. The modulation signal detecting unit 42 outputs a signal in accordance with the intensity of the modulation signal, and the signal that is outputted is inputted to the modulation controlling unit 45.

[0127] In this manner, the optical detecting unit 15 can detect whether the intensity of input light is a predetermined value or less. Therefore, when the intensity of the input light is the predetermined value or less, the controlling unit 14 can control, in accordance with the output of the optical detecting unit 15, the operating point controlling unit 13 so that it keeps the operating point stable. As a result, in the optical communication apparatus having the above configuration, the operating point can be kept stable even when input light is temporarily non-existent.

[0128] Naturally, the optical detecting unit 15 does not output any signals when the intensity of input light is larger than the predetermined value so as to use the optical modulating unit 11. Therefore, the operating point controlling unit 13 controls the operating point to the optimum value only based on the output of the opti-